ТЕХНОЛОГИЯ ПРОДОВОЛЬСТВЕННЫХ ПРОДУКТОВ | TECHNOLOGY OF FOOD PRODUCTS

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ПЕРСПЕКТИВЫ ИСПОЛЬЗОВАНИЯ ПОЛИФЕНОЛОВ В КАЧЕСТВЕ ИСТОЧНИКОВ АНТИОКСИДАНТОВ ДЛЯ ФУНКЦИОНАЛЬНОГО ПИТАНИЯ

PROSPECTS FOR THE USE OF POLYPHENOLS AS SOURCES OF ANTIOXIDANTS FOR FUNCTIONAL NUTRITION

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Аннотация

Согласно данным ВОЗ, наблюдается сниженное потребление фруктов и овощей среди населения. В данный момент, подобный дефицит потребления наблюдается и в России. Сниженное количество в рационе подобных продуктов приводит к росту неинфекционных заболеваний, увеличению оксидативного стресса в организме человека, что в свою очередь приводит и к снижению антиоксидантного статуса. Решить подобную проблему можно добавлением в рацион человека различных функциональных продуктов с различными антиоксидантными компонентами с повышенной антиоксидантной активностью. Подобной активностью обладают полифенолы. Рассматривались 10 групп флавоноидов, а также остальные крупные группы полифенолов. В продуктах питания в основном используются некоторые флавоноиды и антоцианидины. Остальные группы, несмотря на их полезные терапевтические свойства, не используются в пищевой промышленности.

Согласно данным ресурса PubMed наблюдается значительный рост публикативной активности по темам функционального питания и полифенолов за последние 20 лет как за рубежом, так и в России.

Функциональные продукты с полифенолами в большем количестве представлены на зарубежных рынках, нежели на российских. Такие продукты за рубежом представлены в самых различных сегментах рынка – в хлебобулочных изделиях, молочных продуктах, безалкогольных напитках, сухих продуктах и суперфудах. На российском рынке продукты с полифенолами представлены в небольшом количестве в молочных продуктах, безалкогольных напитках и суперфудах, зачастую зарубежными компаниями. В современных условиях такое распределение поднимает проблему импортозамещения и необходимости использования научных пищевых достижений в области молочной продукции и безалкогольных напитков, опережая зарубежные аналоги.

Ключевые слова: полифенолы, антиоксиданты, функциональные продукты, обогащенные продукты, молочные продукты, хлебобулочные изделия, напитки.

Abstract

According to WHO data, there is a reduced consumption of fruits and vegetables among the population. At the moment, a similar consumption deficit is observed in Russia. A reduced amount of such products in the diet leads to an increase in non-communicable diseases, an increase in oxidative stress in the human body, which in turn leads to a decrease in the antioxidant status. This problem can be solved by adding various functional foods with various antioxidant components with increased antioxidant activity to the human diet. Polyphenols have similar activity. 10 groups of flavonoids were considered, as well as other large groups of polyphenols. Some flavonoids and anthocyanidins are mainly used in foods. The remaining groups, despite their useful therapeutic properties, are not used in the food industry.

According to the PubMed resource, there has been a significant increase in publication activity on the topics of functional nutrition and polyphenols over the past 20 years, both abroad and in Russia.

Functional products with polyphenols are presented in greater quantities on foreign markets than on Russian ones. Such products are represented abroad in a variety of market segments - in bakery products, dairy products, soft *drinks, dry foods and superfoods. On the Russian market, products with polyphenols are presented in small quantities in dairy products, soft drinks and superfoods, often by foreign companies. In modern conditions, such a distribution raises the problem of import substitution and the need to use scientific food achievements in the field of dairy products and soft drinks, ahead of foreign analogues.*

Keywords: polyphenols, antioxidants, functional foods, enriched foods, dairy products, baked goods, beverages

Introduction

According to the World Health Organization, there is a reduced consumption of fruits and vegetables among the population. Russian researchers have shown that a deficit in the consumption of fruits and vegetables is observed in Russia at the present time [1–3] . Reduced consumption of various plant products is accompanied by an increase in various non-communicable diseases, an increase in oxidative stress in the human body, which also leads to a decrease in antioxidant status [4] .

The solution to this problem can be functional nutrition, which includes various components. To improve the antioxidant status, various dietary supplements with increased antioxidant activity can be used [5] . Substances known as polyphenols possess such strong activity. They are also known as secondary metabolites of plants, whose molecules contain a large number of hydroxyl groups, which cause antioxidant and other effects [6] . The use of such additives will make it possible to enrich the final food products with antioxidant components, correcting the deficit in the consumption of fruits and vegetables by the population, which is an important task for the food industry as a whole.

In the concept of the roadmap of the national project " FoodNet 2.0" it is also proposed to expand certain areas of the market - alternative sources of raw materials and food, personalized and special nutrition, which considers product segments and the invention of new food composites for specialized and functional nutrition [7] . The expansion of these segments and directions of the market fits well into the concept of obtaining a functional product with increased antioxidant activity, achieved through the use of polyphenolic components.

The purpose of this study is to review the types of polyphenols used in food production with an increased antioxidant effect, to consider Russian and foreign food products that currently use polyphenols.

Substances with an antioxidant effect: meaning and classification

The balance between oxidation and reduction is an important element in maintaining a healthy state of any organism. During the life of living organisms, particles are formed that cause a violation of this balance. Such particles are such radicals as hydroxyl, superoxide, nitric oxide and peroxide. Peroxynitrite, hypochlorous acid, hydrogen peroxide, singlet oxygen and ozone, in turn, are not free radicals, but can lead to the formation of free radicals in living organisms [8] . Such compounds are called reactive oxygen species (ROS) - they are produced during the life of cells, in particular, in mitochondria, during the process of oxygen reduction, hydrogen peroxide can be formed from superoxide [9] . One of the main ways to neutralize ROS in the body is provided by enzymes - catalase and superoxide dismutase, but if the enzymatic link of the antioxidant system is weakened, then in this case we observe the phenomenon of an excess of ROS, or oxidative stress [10] .

With the accumulation of ROS, a state is possible when they themselves begin to influence mitochondria and further increase the amount of ROS received [11] . In addition, they can disrupt the usual mechanisms of cell signaling, oxidize proteins and fats, cause cell apoptosis [12] and cause cognitive dysfunction [13] , as well as accelerate the aging of the body, reducing its performance [11] . Protection of cells from such influences is carried out with the help of various substances - antioxidants - both the aforementioned enzymes and low molecular weight substances (vitamin C, uric acid) or high molecular weight compounds such as phenols and polyphenols act in this role [6] .

Antioxidants are substances that inhibit the oxidation reaction. They are usually divided into water-soluble (glutathione, lipoic acid and uric acid) and fat-soluble (carotene and ubiquinol). Water-soluble antioxidants react with oxidants in the cell cytosol and blood plasma, and fat-soluble antioxidants protect cell membranes from peroxidation [14] . According to their function or mechanism of action, antioxidants can be classified into:

1. free radical-reactive (or "terminators"), which inhibit the formation of free radicals in the initiation phase, and "chain-breakers", which interrupt the reaction at the stage of chain development;
2. metal chelators, which convert metal ions into stable forms that cannot be an electron acceptor;
3. singlet oxygen reactive antioxidants that reduce oxygen to its base state;
4. synergists (or "regenerators"), which increase the activity or restore other antioxidants in the mixture;
5. reducing agents that donate an electron to other oxidizable compounds;
6. inhibitors of oxidative enzymes [15] .

Types of polyphenols and their action

Polyphenols are secondary metabolites of plants and are usually involved in defense against ultraviolet radiation or pathogen aggression [16] . They include a wide range of molecules that have polyphenolic structures, i.e. multiple hydroxyl groups in aromatic rings, as well as molecules with a single phenolic ring such as phenolic acids and phenolic alcohols. Depending on the number of phenolic rings they contain and the structural elements that link these rings to each other, polyphenols are classified into various groups, including phenolic acids, flavonoids, stilbenes, and lignans. It is believed that flavonoids and phenolic acids are the main components that exhibit antioxidant activity in medicinal plants [17] .

Flavonoids constitute the most abundant group of plant polyphenols [17] . Their common structural feature is the diphenylpropane moiety, which consists of two aromatic rings linked via three carbon atoms, which together usually form an oxygen-containing heterocycle. Depending on the type of heterocycle involved, flavonoids are divided into six classes: flavones, flavanones, flavonols, isoflavones, anthocyanidins, and flavanols (or catechins) [18] . Flavonols are the most abundant flavonoids, with quercetin and kaempferol being the most commonly used in foods. Phenolic acids can be divided into two classes: benzoic acid derivatives and cinnamic acid derivatives. Hydroxybenzoic acids such as gallic acid and protocatechuic acid are found in a few edible plants (blueberries, blackberries, strawberries, plums, grapes, mangoes, cashews, hazelnuts, walnuts, tea) [19] . Hydroxycinnamic acids are more common than hydroxybenzoic acids and consist mainly of p-coumaric, caffeic, ferulic, and synapic acids. Gallic acid, a precursor of many tannins, is one of the most studied and promising compounds in the group of hydroxybenzoic acids [20] .

Flavonoids are currently the most studied group of polyphenols. They are divided into 10 generally accepted classes based on the degree of oxidation:

1. Catechins

A large number of catechins are known, the most studied being green tea catechins, namely catechin, epicatechin, epicatechin gallate, epigallocatechin, gallocatechin, catechin gallate, gallocatechin gallate and epigallocatechin-3-gallate. The diversity of structures is explained by the ability of open hydroxyl groups in the composition of molecules to interact with other polyphenols [21] . They have studied antiradical, antibacterial, anticarcinogenic properties and the effect of slowing down cell aging [22,23] . However, during storage, catechins tend to darken, and at the same time, their antioxidant activity decreases [24] , which limits their use in the food industry. Epigallo-3-catechin gallate is one of the best known and most widely used catechins. It can be said that it is also the most studied polyphenol in whey protein-polyphenol complexes, as evidenced by many studies [25,26] . This catechin has a diverse set of functional properties. For example, it may cause a slight decrease in low-density lipoprotein (cholesterol) [27] , and also has an anti-inflammatory effect, it can fight cardiovascular, infectious and neurodegenerative diseases [28–31]

. However, it has a rather low bioavailability due to its instability in the gastrointestinal environment [32] , which has led to widespread studies of its interaction with various proteins.

2. Anthocyanins and anthocyanidins

Anthocyanins are one of the most studied groups of polyphenols [33–36] . The main source of anthocyanins are extracts of various berries or their components (the most common extract from the skin of grapes and an extract from blackcurrant berries). Anthocyanins are widely known in the food industry and are used as a food additive with the label E 163. In addition to their antioxidant properties, these compounds are known for their biological properties associated with the elimination of the consequences of neurodegenerative diseases, diabetes, angiocardiopathy, inflammation and anticancer activity [37,38] . Research is also underway on other therapeutic effects [39] . Small amounts of anthocyanins entering the intestine are reported - various researchers have from 40 to 85% of the encapsulated material, depending on the conditions and methods of encapsulation [40,41] .

3. Leukoanthocyanins

Leukoanthocyanins are derivatives of anthocyanidins. In free form, they exist in large quantities in wines, but they are quite easily oxidized, for example, when heated, as a result of which the amount of anthocyanidins increases. They are responsible for the astringency of the wine, but if they are excessive in taste, excess bitterness appears, and when they polymerize, they precipitate, which causes darkening of the wine.

This group of flavonoids has shown to be potentially effective in the study of their effect in non-alcoholic fatty liver disease (excessive deposition of fatty particles in hepatocytes) [42] .

4. Flavanones

They are colorless ketones, often found in plants in the form of glycosides. In total there are 15 compounds of this type [43] . The most common are eriodictyol and hesperetin in plant tissues, naringin in grapefruit peel, and hesperidin in orange and tangerine peel. Hesperetin is a derivative of eriodictyol, and hesperidin is in turn a glycoside of hesperetin [44] . It is these polyphenols that give bitterness to the taste of the considered citrus fruits. These compounds belong to the vitamin P group [45] .

Eriodictyol is found in small amounts in almonds and pistachios [46] , but is also widely distributed in small amounts in a wide variety of plants, such as sorghum [47] .

5. Flavanonols

This is a subclass of flavanoids that contain two or more oxygen atoms, such as 3-hydroxyflavanol or 2,3-dihydroxyflavonol. The most well-known examples of substances in this subclass are dihydroquercetin (taxifolin), dihydrocampferol (aromaderin) and engeletin (dihydrocampferol-3-rhamnoside). Flavanonol glycosides are present in large quantities in plants [48] .

Dihydroquercetin is found in large quantities in the butt of the Siberian and Daurian larches [49] . It is included in the State Register of Medicinal Products as a pharmaceutical substance. Possessing a fairly large number of positive effects [50-52] , it is less toxic than its predecessor quercetin [52] . In the dairy industry, it is used as an antioxidant to increase the shelf life of canned milk and products [53] and may enhance the growth of lactic acid bacteria [54] .

Enegeletin is found in the skin of grapes, is found in wine, and is also found in small amounts in *Hymenaea martiana* [55] . According to the international patent classification, it refers to traditional herbal medicines according to codes A61K 36/00 and A61P 43/00.

6. Flavones and Isoflavones

Flavones and isoflavones are a fairly extensive subclass of polyphenols (the most common are chrysin, apigenin, acacetin, luteolin, diosmetin, chrysoeriol, diuretin and tricine). Of the flavones in human nutrition, rutin (3-rhamnoglucoside quercetin), which has the activity of vitamin P, is of the greatest interest. It should be noted that this group of substances of their flavonoids is limited in use, since reactions of reversible cleavage of the pyran ring during alkalization under mild conditions with further formation of chalcones are possible. It is this reaction mechanism that also proceeds with amine-containing compounds, including proteins, leading to the destruction of the original flavone molecule (Figure 1).

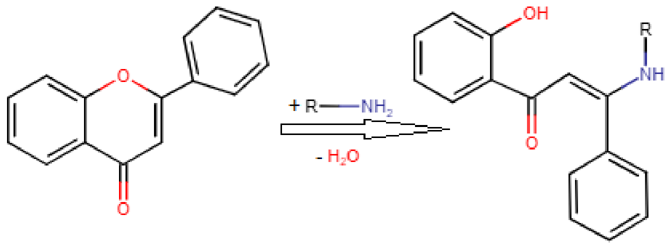

Figure 1. The reaction of flavones with amine-containing compounds

Isoflavones differ in the position of the side phenyl ring, which is in the C-2 position rather than the C-3 position. Compounds of this type can be found in the root of licorice or harrow [56] . Their high content in soybeans is noted with the definition of these substances as phytoestrogens with high biological activity and the ability to inhibit some isoforms of P450 cytochromes, which can affect the metabolism of pharmacological drugs and change the detoxification function.

7. Flavonols

A rather extensive subclass of flavonoids, a characteristic feature is the presence of OH - groups in various positions, which just explains the large number of representatives of the subclass. Kaempferol and quercetin are the best known substances of this series.

Kaempferol is a 3,4',5,7-terahydroxyflavone found in a wide variety of vegetables and fruits: apples, grapes, tomatoes, green tea, green beans, peaches, blackberries, and raspberries [57, 58] . It is used in the manufacture of soft drinks [59] and in sports nutrition [60] .

Quercetin is one of the most studied polyphenols. Contained in a large number of plants, fruits and vegetables - lovage, buckwheat, onions, apples, peppers, garlic, red grapes [61] . It has a fairly large number of positive effects - it activates mitochondrial biogenesis, which leads to an increase in the number of mitochondria in brain cells that have undergone traumatic brain injury [62] . It has an anti-inflammatory effect [63] .

8. Chalkons

A subclass of compounds with an open pyran ring, which is why they are quite reactive compounds, which means they can enter into dimerization, glycosylation and reduction reactions. They show antibacterial, antifungal and antitumor properties [64] , and some members of the class have also shown the ability to block potassium channels [65] . Contained in the bark of the apple tree, grapes [66] and hops [67] .

9. Dihydrochalcones

Dihydrochalcones are derivatives of chalcones, differ from chalcones in the presence of a saturated propane fragment. Depending on the nature of the substituents in the rings, they have a different severity of sweet taste; in the food industry they are used as sweeteners [68] , for example, the food additive E959 - neohesperidin hydrochalcone. It is mainly found in various parts of the apple tree, such as roots, leaves, shoots and seeds [69] .

10. aurons

Aurones are presented as cis- and trans-isomers. The main difference from other flavonoids is the content of the benzofuran fragment associated with benzylidiene. These compounds can be found in various plants, such as snapdragon and cosmea [70] , brown algae [71] . By analogy with other flavonoids, it is assumed that there are similar biological effects [72] , but only the antifungal properties of these compounds have been proven [73] .

Thus, from the classes and subclasses of polyphenols and individual compounds discussed above, one can single out the potential possibility of their use as a functional ingredient in products. So, stilbenes in the face of resveratrol and pterostilbene show themselves as independent substances; all flavonoids have problems with bioavailability, and, basically, the protein acts as a transport molecule. Catechins have been extensively studied, and the best known representative is epigallocatechin-3-gallate (EGCG). This compound is the most studied within the food industry and various pharmaceutical effects. Anthocyanidins are also quite widely studied, but if in the case of catechins the clear leader of the subclass is EGCG , then in the case of anthocyanidins there is no such substance. The raw materials in this case are the most homogeneous - red fruits and berries, mainly red grapes. In the case of working with flavanones and flavanonols, there is a possibility that, in addition to problems in extraction (some substances are found in oak bark, for example), there will be problems with the organoleptic part (they have a pronounced bitter taste), which does not occur in the case of anthocyanins (the most common berry sweet and sour taste). Quercetin and kaempferol are found in a wide variety of fruits and plants. Also, these substances are individual, unlike anthocyanin extracts with a diverse profile of substances. Chalcones, dihydrochalcones and aurones are rather poorly studied.

Analysis of food fortification and functional food market.

People consume a large number of functional foods - various bakery products, dairy products, meat and fish semi-finished products, alcoholic and non-alcoholic drinks, snacks and confectionery. A special category is to highlight baby food, where enrichment with various useful additives has long been practiced. In most of these categories, there is a growing demand for functional and herbal products. Also, according to the PubMed resource , the publication activity on the topic under discussion has been growing over the past 20 years:

Table 1 - the number of scientific publications for the keywords " Functional Foods " and " Functional food POLYPHENOLS " according to PubMed .

Request/year	Functional _ food »	Functional _ food POLYPHENOLS »
2000	205	2
2001	236	2
2002	248	3
2003	262	5
2004	287	7
2005	356	7
2006	369	fourteen
2007	435	four
2008	477	eleven
2009	536	2
2010	655	27
2011	776	3
2012	932	39
2013	1065	61
2014	1266	7
2015	1376	eight
2016	1506	81
2017	1729	108
2018	2042	147
2019	2253	134
2020	2538	157
2021	2631	141

The data shown are also consistent with the position of Russian researchers in this field, who recently presented the FoodNet 2.0 concept as part of the national technology initiative. The concept of " FoodNet " is the systematic development of various segments of the food industry market, as well as the formation of a globally competitive Russian "food industry 4.0" - new production, logistics and marketing solutions based on digitalization, network market models and customization of products and services, biotechnology, resource efficiency . Within the framework of this model, functional foods act as participants in two segments of the food industry market at once - as an alternative source of food or personalized and special nutrition. It is predicted that the capitalization of these segments will double by 2035 [7] . However, when using various new technologies, one should not forget about the issue of security [74] .

The positions of the most famous companies in the market of functional and fortified food products are considered below. The leaders of Russian and foreign ratings in terms of revenue in the specified industry were taken as a basis.

1. Bakery products

The Karavay company (St. Petersburg) has in its assortment milk bread with apple, enriched with zinc, iron and iodine, vitamins B1, B2, B6, C, PP and prebiotic inulin. Also bread "Farmer" hearth with the addition of vitamins E, H and group B, calcium, manganese, iron, chromium, and bread "Starorussky" enriched with vitamins and microelements. Bakery and confectionery holding "Kolomenskoye" has 3 types of bread with various additions of large quantities of pumpkin, flax and sunflower seeds, which provides products with more vitamins and minerals than in ordinary bread. JSC "LIMAK" offers a choice of "Iodized" loaf, enriched with iodized protein. Also, like BKH "Kolomenskoye", they use flour of various origins in their production to enrich their products with various vitamins and macro- and microelements. JSC "First Bakery" has a whole line of bread for a healthy diet - there are breads with a low glycemic index, enriched with various additives of pumpkin and flax flour, as well as bread "Grain with calcium", containing a vitamin and mineral complex with vitamins B1, B2, B6, folic acid, as well as calcium and iron. But the most interesting representative for this study is Champion-Leader bread with a high content of phospholipids and vitamin E (tocopherol). In general, the specified line of breads is shown as products for a healthy diet. The group of companies "Darnitsa" (brand "Aladushkin") also has in its assortment a line of so-called "healthy breads" enriched with various vitamins and minerals. Other companies do not produce such useful products (KBK Cheryomushki, SMAK, Volzhsky Pekar and Khlebzavod No. 28). The products of local producers represented by Stavropol Dairy Plant JSC were also considered. MKS produces Fermersky bread, which contains Jerusalem artichoke flour, which contains various vitamins (A, groups B and C), macro- and microelements.

The company " Nestlé " produces under the brand " Oats & More " a series of various oatmeal for breakfast, containing both additives in the form of raisins or almonds, and enriched with a vitamin-mineral complex (7 vitamins, riboflavin and iron are declared). Large company Mondelez International produces a large number of fortified bakery and confectionery products under various brands. So, under the Belvita brand , various cookies are produced, enriched with vitamins B2, B6, as well as thiamine, niacin, riboflavin and iron. Brand " Enjoy " life Food " also produces various cookies, but they are not enriched, but on the contrary, they are free of various allergens and gluten. " Lu " produce crackers, toasts and crackers, in their assortment they have crackers enriched with iron, magnesium, folic acid and vitamins B1, B2, B6 and E. Bars " Perfect Snacks with added superfoods, and high in calcium, potassium, niacin, magnesium, iron, and vitamin E. Associated british food Plc owns the Burgen brand , which produces a variety of prebiotic-infused breads. Another brand of theirs, Kingsmill , sells breads with vitamin supplements (vitamin D , iron and calcium) and increased fiber content.

Considering Russian and foreign bakery and confectionery products, it should be noted that despite the presence on our market of individual products in the range of the above brands, in the foreign market such niches are immediately entered by large brands and companies whose goal is to produce enriched and functional products. The main additives are B vitamins and minerals in the form of micro and macro elements. Polyphenols were absent in Russian bakery products; abroad, it is practiced to add small amounts of various berries (for example, raisins in Oats & More cereal), which increases the amount of polyphenols in the final product.

2. Dairy products and drinks.

One of the largest groups of functional foods. Brands " Danone " - "Actual" (whey with the addition of fruit juice and a vitamin complex with vitamin D), a series of baby food "Rastishka" (also with the addition of vitamin D), a series of vegetable-based soft drinks " ALPRO " with the addition of vitamins D and B 12, Actimel fermented milk products (D 3, B 6 and probiotics). Fonterra is practically not represented in Russia , one of its brands is Anchor , which produces various yogurts enriched with vitamins A and D , calcium, and various prebiotics. PepsiCo brands (represented in Russia by Wimm-Bill-Dann) - products of the Mazhitel line (a cocktail of milk, whey and fruit juice), the Immunele line in the form of a fermented milk product with the addition of vitamins D 3 and B6. Enriched with calcium and a complex of 6 vitamins (C, B1, B6, B9, B12, PP) Toptyzhka milk from the Milkom company. "Komos-Group" company - the entire line of products " Fitness time " consists of superfoods (non-alcoholic drink based on whey, fruit juice and matcha tea), protein yogurts (yogurts with the addition of milk protein), fortified milk (vitamin-mineral premix: calcium phosphate, magnesium citrate, zinc sulfate, D 3 and B12) and "albumin curd" (curd mass with the addition of hydrolyzed collagen, whey and albumin). Company « Foodland » - fermented milk product «Elanochka» enriched with vitamins A, C, B1 and B2. The local manufacturer of dairy products, Stavropolsky Dairy Plant, also has products with various additives in its assortment. Pasteurized milk with prebiotic lactulose, thermostatic “Snezhok” with probiotic L. Rhamnosus LGG, “Pure” Bioyogurt with five microorganisms (*Str. thermophilus, L. bulgaricus, Bifidobacterium sp, L. plantarum, L. acidophilus, L. casei, L. rhamnosus LGG*), bio-yogurt with the addition *of L.casei* , milkshake enriched with protein, vitamin D3 and calcium "Active Milk", sour-milk bio-ice cream with probiotic (acidophilus bacillus) and prebiotic (lactulose).

In the range of soft drinks, fruit juices are the predominant type of product. A significant market share is occupied by the PepsiCo company with the brands J 7, Lyubimy, Fruktovy Sad, Ya. Together with them, brands of other companies are presented on the shelves, such as Dobry, Sady Pridonya, etc. A distinctive feature of such drinks is the absence of the need to add other functional additives there - fruits and vegetables from which these juices or enriched with various micro and macro elements, vitamins. However, the Nestle company abroad produces a line of nutritional drinks using milk proteins, soy and stevia - " Boost ". This fortification is more appropriate for sports nutrition drinks, which are not the focus of this review. Note that all drinks of this brand are enriched with a large number of vitamins and microelements - vitamins D, A, C, E, K, B6, B12 calcium, iron, potassium, thiamine, riboflavin, niacin, folic acid, biotin, pantothenic acid, phosphorus, iodine, magnesium, zinc, selenium, copper, manganese, chromium, molybdenum, chloride and choline. In Russia, stevia is mainly used as an independent sugar substitute and in various confectionery products.

In this segment, it is not possible to divide companies and brands into Russian and foreign ones, due to their close coexistence. The main functional additive in dairy products is vitamin D and B vitamins . Sometimes vitamins of groups A and C are added, as well as various micro and macro elements or their complexes. Within the production of various yoghurts, there is a tendency to introduce various pre- and probiotics. Polyphenols are present in small quantities both in Russian holdings (Komos Group with a line of superfoods based on whey) and abroad (Mazhitel from PepsiCo).

3. Dry Foods/Superfoods

Abroad, dry products in the form of dietary supplements are widely represented, packaged in the form of bags with a zip - lock fastener for reusable use from 100 to 500 grams. So, for example, in the top 100 most popular products ordered through the amazon platform . com got the following superfoods:

1) Organic Acai Berry Powder, positioning itself as freeze-dried acai (vegetable euterpe), with a high content of vitamins A and C, iron and calcium. It is used as a base for making various juices, smoothies, yoghurts [75] .

2) Laird Superfood Instafuel Matcha, this superfood claims two main components - powdered green tea and original non-dairy creamer powder (includes coconut milk powder, coconut sugar and coconut oil). It contains a large amount of vitamins A, C, as well as calcium [76] .

3) Sweetwell Keto Sugar-Free Meringue Cookies is not a superfood, but it captures the general trend quite accurately. These meringue cookies come in a variety of flavors and are low in carbs to support a keto diet. The manufacturer focuses on the use of stevia as a sweetener. The enrichment of various elements depends on each specific taste. So, cookies with chocolate flavor, due to the large amount of cocoa, have a large amount of magnesium and potassium [77] .

4) Country Farms Super Reds Energizing Polyphenol Superfood is a polyphenol superfood dry blend containing 48 different berries and fruits rich in antioxidants, phytonutrients and fiber [78] .

The rest of the products on this list are dietary supplements or specific compounds.

Also the previously mentioned company Mondelez International owns the Tang brand , which specializes in low-sugar beverage powders fortified with vitamins C and D. Such a product can be classified as a superfood. The Associated Company british food Plc " with its brand " Anthony 's Goods has a fairly large selection of superfoods - and various fruit and vegetable powders, flour, sugar substitutes and more.

Similar products are beginning to appear on the Russian markets, although they have not yet gained such great popularity. The brands " Royal " are engaged in the sale and production of such superfoods. forest " and " SpirulinaFood ". Royal products forest " is mainly made from a cocoa substitute - carob. It is high in fat and protein, high in fiber, low in carbohydrates, and contains gallic acid [79] and SpirulinaFood puts more emphasis on spirulina powders and supplements. However, the products of these companies are not positioned as functional or enriched with any elements.

The main difference between superfoods and other types of products can be called their independence - they are made exclusively from plant components, and sometimes they themselves can act as food additives. All presented positions contain a large amount of vitamins A and C and various micro and macro elements.

Polyphenols in foreign superfoods and dry products are presented much better than in Russia - abroad they produce and buy a very large amount of dry products with a large amount of polyphenols in the composition, in addition to other enriched items. There is no wide range of manufacturers of such products on the Russian market, despite the popularization of this segment.

Conclusion

Polyphenols have been shown in research to be useful components that can be used in different food systems and exhibit different properties. However, market saturation with products with polyphenols is low. The largest number of such products is produced abroad - in particular, superfoods, dry foods and the presence of bakery products with polyphenols in the composition stand out. In Russia, similar products are currently presented in small quantities on the shelves by foreign companies in the dairy segment. Superfoods are represented by Russian companies, but also in small quantities. Thus, the issue of the lack of such products in the segment of bakery products and dry products is raised, as well as the problem of import substitution within the segment of soft drinks and dairy products. In such a situation, it is worth focusing on the need to use scientific nutritional achievements in the field of dairy products and soft drinks, ahead of foreign analogues.

The market for functional products is growing every year, both in Russia and abroad, but the foreign market has long been saturated with functional products, while Russian markets are just beginning to follow the trend of "healthy" nutrition. New companies are emerging, customer interest is increasing and publishing activity has been growing over the past ten years, new food concepts are being developed.

The following polyphenols and flavonoid classes were not present in foodstuffs: phenolic acids, stilbenes, chalcones, aurones, leukonanthocyanidins and most flavonoids - catechins, flavanones, flavanonols, flavanols (quercetin and kaempferol). Despite this, the demand for such products is growing both among consumers and among manufacturers and researchers, as literature data show us. This suggests that functional products with the above polyphenols may soon appear.

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